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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01S 3/02	A1	(11) International Publication Number: WO 00/26687 (43) International Publication Date: 11 May 2000 (11.05.00)

(21) International Application Number: PCT/US99/21963

(22) International Filing Date: 21 September 1999 (21.09.99)

(30) Priority Data:
09/182,701 29 October 1998 (29.10.98) US

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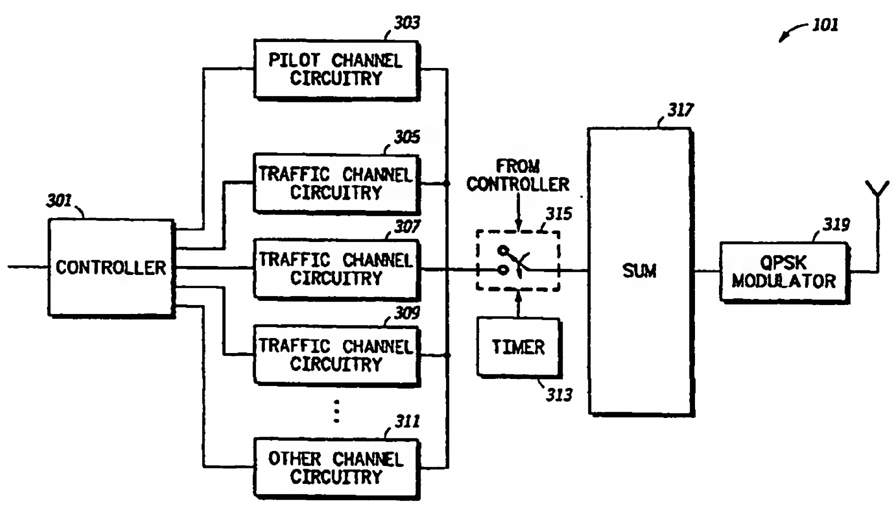
(81) Designated States: BR, JP, KR, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: REMOTE UNIT LOCATION IN A COMMUNICATION SYSTEM



(57) Abstract

During time periods when a remote unit (113) wishes to perform a location measurement, a near–in base station (101) periodically reduces (possibly down to zero) the transmission power of the down–link communication signal (116) transmitted by the base station (101) for a short time period in order to aide in locating the remote unit (113). By periodically reducing the power of the signal (116) transmitted by the near–in base station (101), a substantial part of the interference received by the remote unit (113) is reduced, thus improving the Ec/Io ratio for detection of weak neighbor signals. Because Ec/Io is reduced for weak neighbor transmissions, the remote unit (113) can more accurately determine its location when the remote unit (113) is close to the near–in base station (101).

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REMOTE UNIT IN A COMMUNICATION SYSTEM

Field of the Invention

The present invention relates generally to wireless communication systems and, in particular, to a method and apparatus for remote unit location in a wireless communication system.

Background of the Invention

It is well known that a remote unit's location within a wireless communication system may be determined using a trilateration method. According to such a method, distances between the remote unit and multiple base stations are calculated based on a measurement of a time delay of a signal traveling between the remote unit and each base station. Such a prior-art method for calculating a remote unit's location is described in US Pat. No. 5,508,708 "METHOD AND APPARATUS FOR LOCATION FINDING IN A CDMA SYSTEM" by Ghosh et al. and incorporated by reference herein. As described in Ghosh et al., when location of a remote unit is desired, the uplink signal transmitted from the remote unit to multiple base stations is analyzed to determine propagation delay differences at each base station. From these propagation delay differences, a distance is calculated from each base station to the remote unit, and the location of the remote unit is determined. Similarly, propagation delay differences can be calculated at the remote unit from a downlink communication signal (e.g., pilot signal) transmitted by multiple base stations, and a distance from each base station can be calculated by the remote unit in order to determine its location.

Although remote units utilizing prior-art methods of location estimation can determine their relative location, these methods are limited in that remote units are only capable of determining location when they are beyond a certain distance from a base station. More particularly, as a remote unit gets close to a base station, the base station's transmission is received stronger, and constitutes a

strong interference to the signals received from far (neighbor) base stations. Because of this, there is an area around each base station where a remote unit will be incapable of receiving signals transmitted from other base stations. Thus a need exists for a method and apparatus for remote unit location in a communication system that is capable of allowing for a remote unit close to a base station to estimate its location.

Brief Description of the Drawings

FIG. 1 is a block diagram of a communication system in accordance with the preferred embodiment of the present invention.

FIG. 2 illustrates a Time Difference Of Arrival (TDOA) location technique in accordance with the preferred embodiment of the present invention.

FIG. 3 is a block diagram of a base station sector in accordance with the preferred embodiment of the present invention.

FIG. 4 is a flow chart illustrating operation of the base station of FIG. 1 in accordance with the preferred embodiment of the present invention.

FIG. 5 is a block diagram of a base station sector in accordance with an alternate embodiment of the present invention.

FIG. 6 illustrates operation of sectorized base stations in accordance with a preferred and alternate embodiment of the present invention.

Detailed Description of the Drawings

To address the need for remote unit location, during time periods when a remote unit wishes to perform a location measurement, a near-in base station periodically reduces a power of a downlink communication signal transmitted by the base station in order to aide in locating the remote unit. By periodically reducing the power of the signal transmitted by the near-in base station, a substantial part of the interference received by the remote unit is reduced, thus improving the detection of weak neighbor signals. Because interference is

reduced for weak neighbor transmissions, the remote unit can more accurately determine its location when the remote unit is close to the near-in base station.

The present invention encompasses a method for aiding remote unit location in a communication system. The method comprises the steps of determining that a location of a remote unit needs to take place and periodically reducing a power of a transmission in order to aide in locating the remote unit when it is determined that the location of the remote unit needs to take place.

The present invention additionally encompasses a method for aiding remote unit location in a communication system. The method comprises the steps of determining that a location of the remote unit needs to take place and determining a time period when neighboring base stations will be actively transmitting a downlink communication signal. A power of a transmission from a base station is periodically reduced during the time period when neighboring base stations will be actively transmitting the downlink communication signal, in order to aide in locating the remote unit.

Finally, the present invention encompasses a base station comprising channel circuitry outputting a signal. The base station additionally comprises a switch having the signal as an input and periodically outputting the signal having a reduced power during a time period when neighboring base stations are actively transmitting a downlink communication signal.

Turning now to the drawings, wherein like numerals designate like components, FIG. 1 is a block diagram of communication system 100 in accordance with the preferred embodiment of the present invention. In the preferred embodiment of the present invention, communication system 100 utilizes a Code Division Multiple Access (CDMA) system protocol as described in Cellular System Remote unit-Base Station Compatibility Standard of the Electronic Industry Association/Telecommunications Industry Association Interim Standard 95A (IS-95A), which is incorporated by reference herein. (EIA/TIA can be contacted at 2001 Pennsylvania Ave. NW Washington DC 20006). In alternate embodiments of the present invention communication system 100 may utilize other analog or digital cellular communication system protocols such as, but not

limited to, the Narrowband Advanced Mobile Phone Service (NAMPS) protocol, the Advanced Mobile Phone Service (AMPS) protocol, the Global System for Mobile Communications (GSM) protocol, the Personal Digital Cellular (PDC) protocol, or the United States Digital Cellular (USDC) protocol. Communication system 100 includes base stations 101-103, and remote unit 113. As shown, base stations 101-103 are transmitting downlink communication signals 116. Although not shown, one of ordinary skill in the art will recognize that base stations 101-103 are suitably coupled to necessary infrastructure equipment such as Centralized Base Station Controllers (CBSCs), Mobile Switching Centers (MSCs), and the like.

During time periods when remote unit 113 wishes to perform a location measurement, remote unit 113 utilizes a Time Difference Of Arrival (TDOA) technique to perform the location measurement. For a TDOA method of location, the observed time difference between pairs of signals (e.g., pilot signals) arriving at remote unit 113 from three or more base stations are used to compute the location of remote unit 113. This method is illustrated in FIG. 2. Here, three BSs are shown as base station 201, base station 202, and base station 203. Remote unit 204, by observing the time difference in arriving signals between base station pairs 201 – 203, 202 - 203, and 201-202 can establish the hyperbolae or "lines of position" (LOPs') indicated as LOPs 205-207. In this method therefore, the location estimate can be obtained without knowledge of the absolute arrival time of the signal from each base station at the remote unit. Only time differences in arrival are significant.

As discussed above, although remote units utilizing prior-art methods of location estimation can accurately determine their location, these methods are limited in that they are only capable of determining the location of remote units that are beyond a certain distance 110 from base stations 101-103. In order to address this problem, in the preferred embodiment of the present invention, the near-in base station 101 periodically reduces a power of downlink communication signal 116 transmitted by base station 101 in order to aide in locating remote unit 113. By periodically reducing the power of signal 116 transmitted by a near-in base station, a substantial part of the interference received by remote unit 113 is reduced, thus improving the Ec/Io ratio for detection of weak neighbor pilot signals. Because Ec/Io is reduced for weak neighbor pilot transmissions, remote

unit 113 can more accurately determine its location when the remote unit is close to a base station. (Ec is the Received Energy per CDMA "Chip" (bit duration at the Spread Spectrum high rate, 1/1.2288MHz=813.8nsec for IS-95 CDMA), and Io is the spectral density of the total received CDMA interference. Thus, Ec/Io is the received signal to noise ratio at the spread spectrum high bandwidth.)

FIG. 3 is a block diagram of a single sector of base station 101 of FIG. 1 in accordance with the preferred embodiment of the present invention. Base station 101 comprises controller 301, pilot channel circuitry 303, traffic channel circuitry 305-309, other channel circuitry 311, switch 315, timer 313, summer 317, and modulator 319. In the preferred embodiment of the present invention base station 101 is a Motorola SC9600 base station having three sectors, each covering 120 degrees.

Base station 100 utilizes multiple classes of channels defined for forward transmission. In the preferred embodiment, the traffic channels are similar to existing CDMA traffic channels and are used for voice and signaling. CDMA traffic channels are described in detail in IS-95A. As described in IS-95A, the transmission rate of this channel may vary dynamically. Additionally, soft handoff (simultaneous communication utilizing more than one traffic channel circuit 305-309) is supported utilizing traffic channel circuitry 305-309. Pilot channel circuitry 303 is utilized to broadcast a pilot channel from base station 101. Such a pilot channel is described in IS-95A section 7.1.3.2 and is utilized to provide timing and phase synchronization to aid in subsequent demodulation of a transmitted signal. Other channel circuitry 311 comprises all other channels utilized by base station 101 such as paging channels, access channels, . . . , etc.

Operation of base station 101 in accordance with the preferred embodiment of the present invention occurs as illustrated in FIG. 4. At step 401 a determination is made by controller 301 that a location of a remote unit needs to take place. In the preferred embodiment of the present invention the determination is based on a location request being received from a regional entity such as a MSC, operations center, or perhaps within a connected network such as Public Switched Telephone Network (PSTN). The location request, which includes identification information on the remote unit that is to be located enters controller 301, as well as other controllers existing within neighboring base stations. In response, at step 403, controller 301 directs switch 315 to periodically

switch to an open position, causing transmission from the sector to be periodically reduced in power. In the preferred embodiment, switch 315 is instructed to open (ceasing transmission) for a 20 ms period every two seconds.

In an alternate embodiment of the present invention, the opening of switch 315 causes the transmission from base station 101 to be periodically attenuated by an attenuator. Such a base station sector is shown in FIG. 5. As is evident, the base station in accordance with the alternate embodiment of the present invention comprises attenuator 501. Thus, when switch 315 is instructed to open, transmisssions from base station 101 in accordance with the alternate embodiment, are attenuated by attenuator 501 prior to transmission. Although in the alternate embodiment of the present invention base station 101is shown comprising attenuator 501, one of ordinary skill in the art will recognize that other forms of attenuation are possible. For example, attenuation may be accomplished in power amplifiers existing within channel circuitry 303-311.

In the preferred embodiment of the present invention all switches within base station 101 are directed to open or close during the same 20 ms time period when switches in neighboring cells are open. Thus in the preferred embodiment of the present invention, all sectors of base station 101 transmit, or cease from transmitting downlink communication signal 116 simultaneously. During the time period when transmission has ceased, transmission from neighboring base stations is taking place. In an alternate embodiment of the present invention, switch 315 is preprogrammed to open when switches operating in neighboring base stations, as well as switches operating in differing sectors of base station 101 are closed. Therefore, in both the preferred and alternate embodiments of the present invention all sectors operating within neighboring base stations 101-103 are synchronized so that during any 20 ms period, only predetermined sectors cease transmission.

Continuing, at step 405 base station 101 transmits a message to remote unit 113, instructing remote unit 113 to perform a location estimation. As discussed above, remote unit 113 performs a location estimation via a TDOA technique. At step 407, base station 101 determines if it has received a location estimation for remote unit 113, and if not, the logic flow returns to step 407, otherwise the logic flow continues to step 409 where base station 101 passes the location estimation to the entity that requested the remote unit's location. Finally,

at step 409, controller 301 instructs switch 315 to remain in a closed position, resuming normal CDMA transmission.

FIG. 6 illustrates operation of sectorized base stations 601-607 in accordance with the preferred and alternate embodiments of the present invention. As shown, each base station 601-607 is divided into three 120 degree sectors 1-21. In the preferred embodiment of the present invention (shown as 500 ms period 620) all sectors of a base station 601-607 cease transmission during the same 20 ms time period when location is desired. Thus, in the preferred embodiment, a cell site, as a whole, will attenuate its power during those time periods when neighboring cell sites, as a whole, are actively transmitting a downlink communication signal at full power. In the alternate embodiment of the present invention, when location is desired, all sectors of base stations 601-607 cease transmission for a 20 ms period every two seconds. This is illustrated in FIG. 6 during 500 ms period 610. As shown, in 500 ms period 610, during a time period when a sector 1-21 ceases transmission, all other neighboring sectors are actively transmitting downlink communication signals. Likewise, during time periods when a sector 1-21 has increased its power, at least one sector 1-21 has reduced its power.

The descriptions of the invention, the specific details, and the drawings mentioned above, are not meant to limit the scope of the present invention. For example, in addition to periodically ceasing transmission on traffic channels and paging channels during location, base stations may cease transmission of any channel without varying from the scope of the present invention. Additionally, although power reduction means 315 is shown as comprising a switch, one of ordinary skill in the art will recognize that any means may be employed to periodically reduce, or cease transmission from an individual base station. It is the intent of the inventors that various modifications can be made to the present invention without varying from the spirit and scope of the invention, and it is intended that all such modifications come within the scope of the following claims and their equivalents.

What is claimed is:

1. A method for aiding remote unit location in a communication system, the method comprising the steps of:

determining that a location of a remote unit needs to take place; and

periodically reducing a power of a transmission in order to aide in locating the remote unit by when it is determined that the location of the remote unit needs to take place.

2. The method of claim 1 wherein the step of periodically reducing the power of the transmission comprises the step of periodically reducing a power of a downlink transmission from a base station to the remote unit.

3. The method of claim 1 wherein the step of periodically reducing the power of the transmission comprises the step of periodically ceasing transmission.

4. The method of claim 1 wherein the step of periodically reducing the power of the transmission comprises the step of periodically attenuating the power of the transmission.

5. The method of claim 1 wherein the step of periodically reducing the power of the transmission comprises the step of periodically reducing the power of a transmission from a base station, wherein the reduction of power takes place during a time period when a plurality of neighboring base stations are actively transmitting.

6. The method of claim 5 further comprising the step of periodically increasing the power of the transmission from the base station during time periods when a neighboring base station is reducing a power of a transmission.

7. A base station comprising:

channel circuitry outputting a signal; and

a switch having the signal as an input and periodically outputting the signal having a reducing power during a time period when neighboring base

stations are actively transmitting a downlink communication signal, in order to aide in locating the remote unit.

8. The base station of claim 7 wherein the signal having a reduced power comprises a signal having no power.

9. The base station of claim 7 wherein the signal having a reduced power comprises a signal having attenuated power.

10. The base station of claim 7 wherein the switch periodically operates in an open position to reduce the power and periodically operates in a closed position to increase the power during time periods when a neighboring base station is reducing a power of a transmission.

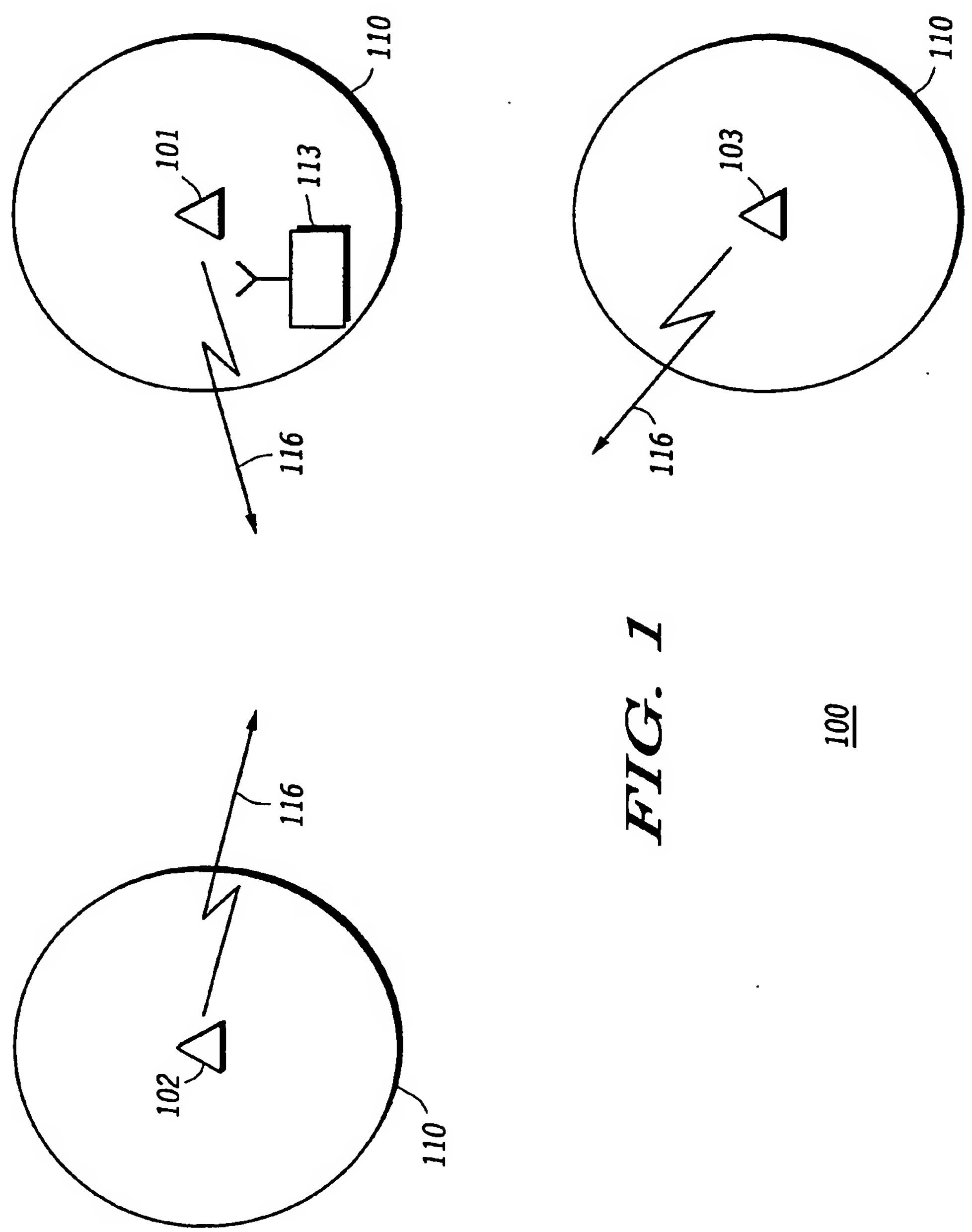

FIG. 1

100

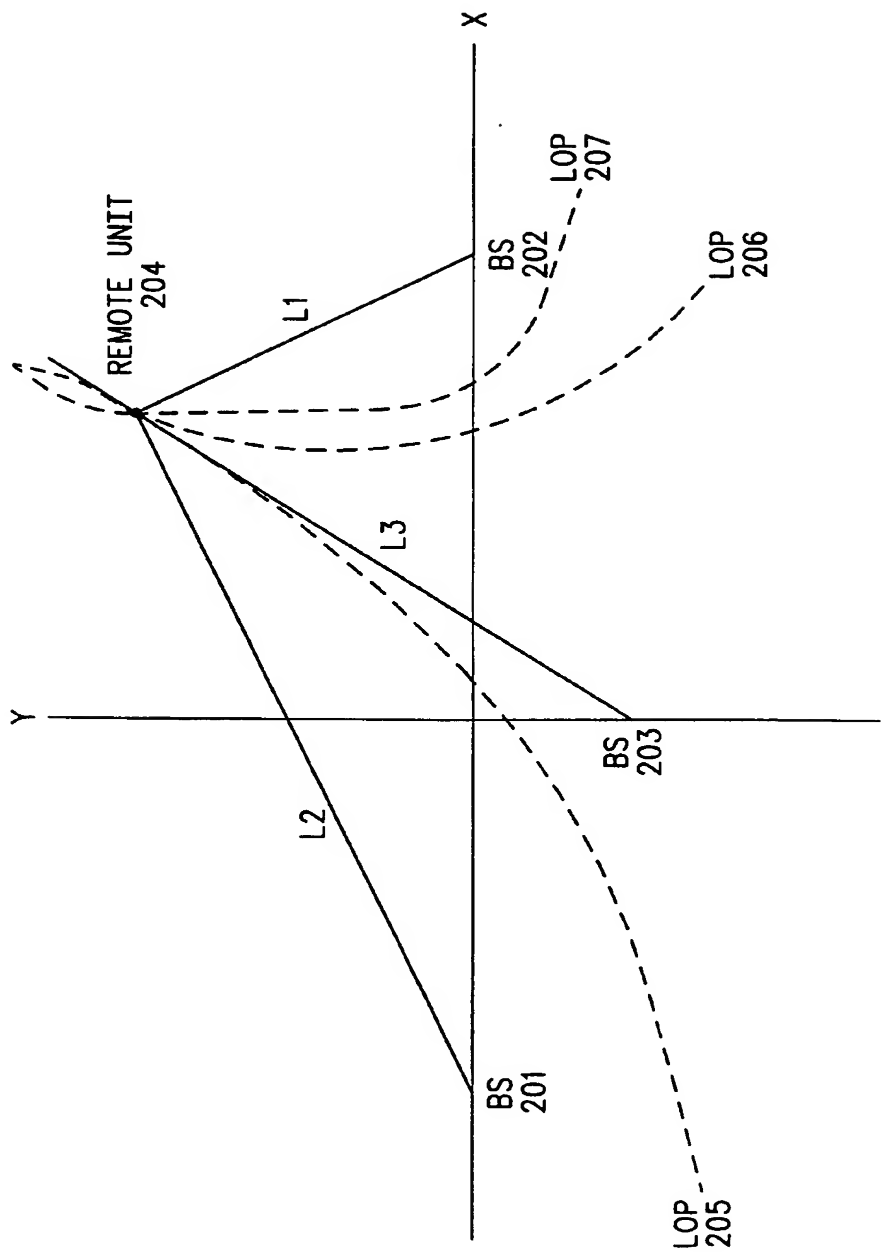
X
Y
REMOTE UNIT
204
L1
BS
202
LOP
207
LOP
206
L3
L2
BS
203
BS
201
LOP
205

FIG. 2

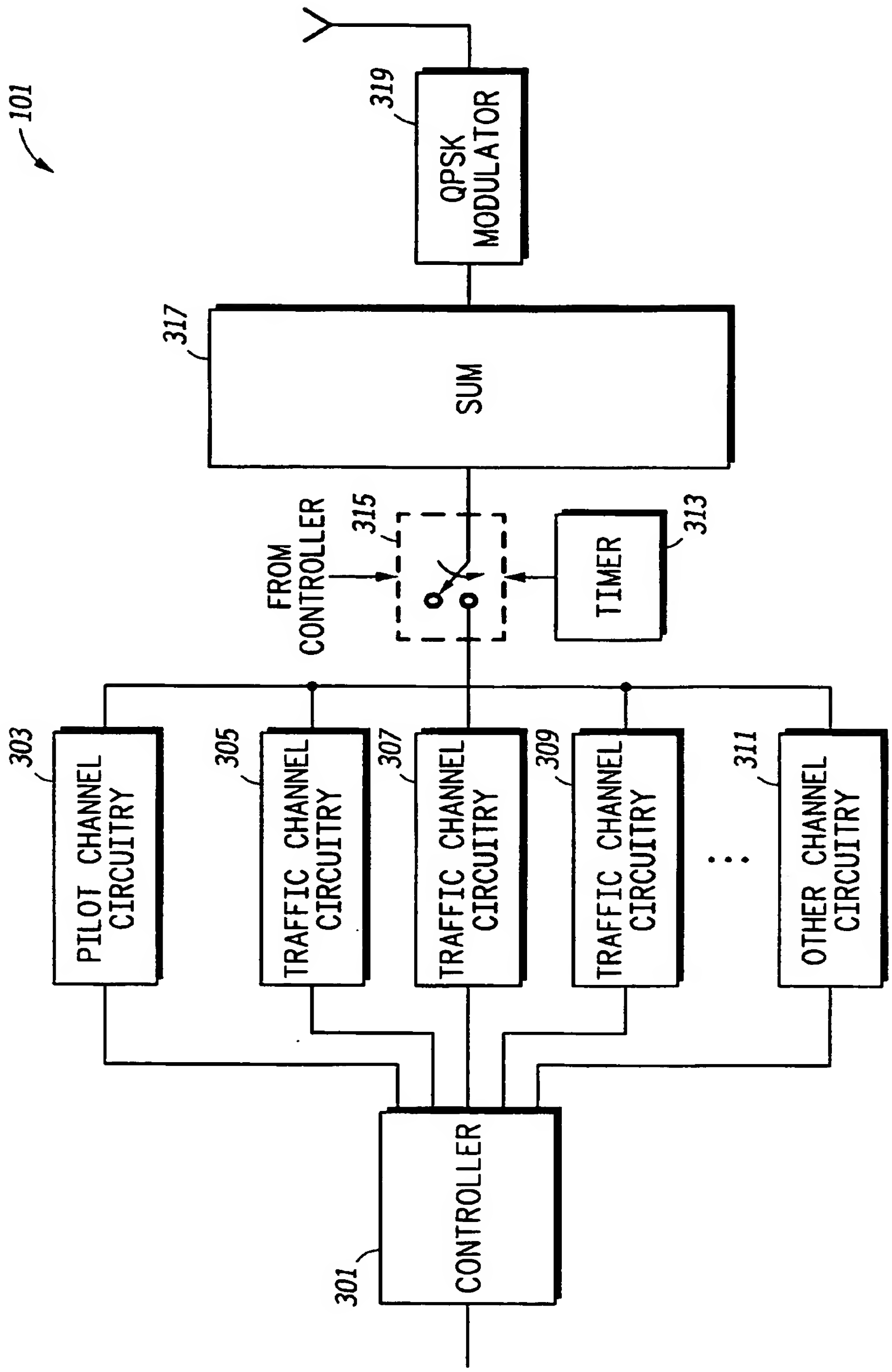
101
319
QPSK MODULATOR
317
SUM
FROM CONTROLLER
315
TIMER
313
303
PILOT CHANNEL CIRCUITRY
305
TRAFFIC CHANNEL CIRCUITRY
307
TRAFFIC CHANNEL CIRCUITRY
309
TRAFFIC CHANNEL CIRCUITRY
311
OTHER CHANNEL CIRCUITRY
301
CONTROLLER

FIG. 3

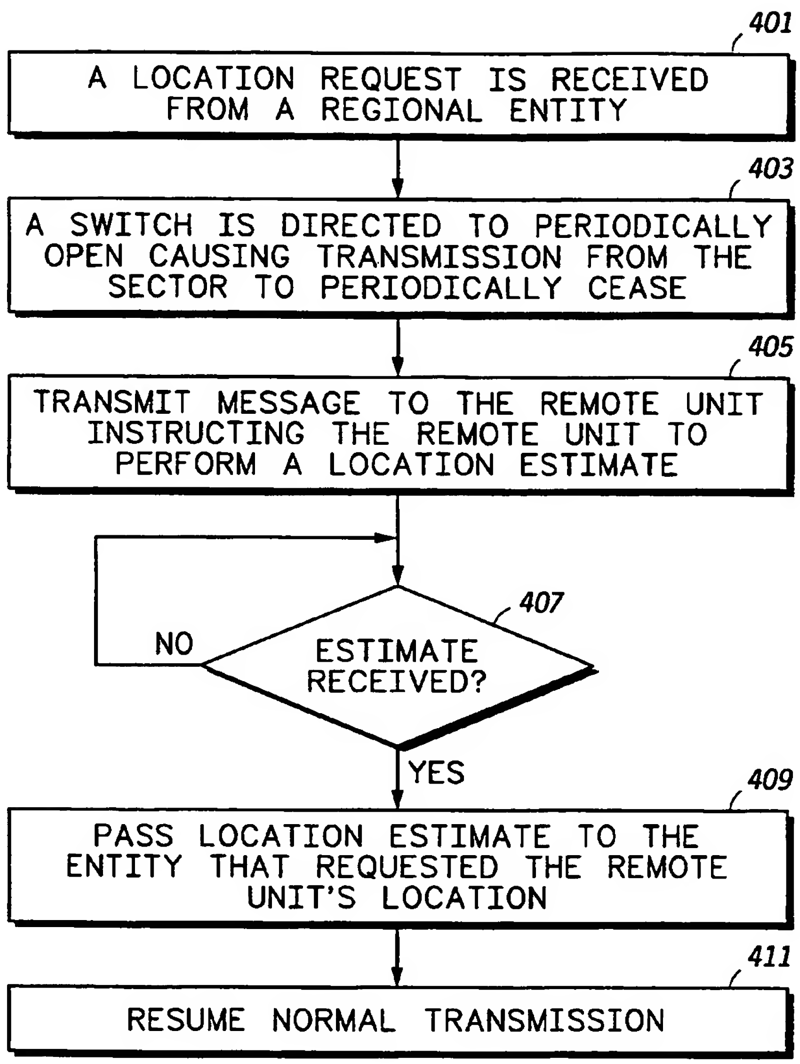
401
A LOCATION REQUEST IS RECEIVED FROM A REGIONAL ENTITY
403
A SWITCH IS DIRECTED TO PERIODICALLY OPEN CAUSING TRANSMISSION FROM THE SECTOR TO PERIODICALLY CEASE
405
TRANSMIT MESSAGE TO THE REMOTE UNIT INSTRUCTING THE REMOTE UNIT TO PERFORM A LOCATION ESTIMATE
407
ESTIMATE RECEIVED?
NO
YES
409
PASS LOCATION ESTIMATE TO THE ENTITY THAT REQUESTED THE REMOTE UNIT'S LOCATION
411
RESUME NORMAL TRANSMISSION

FIG. 4

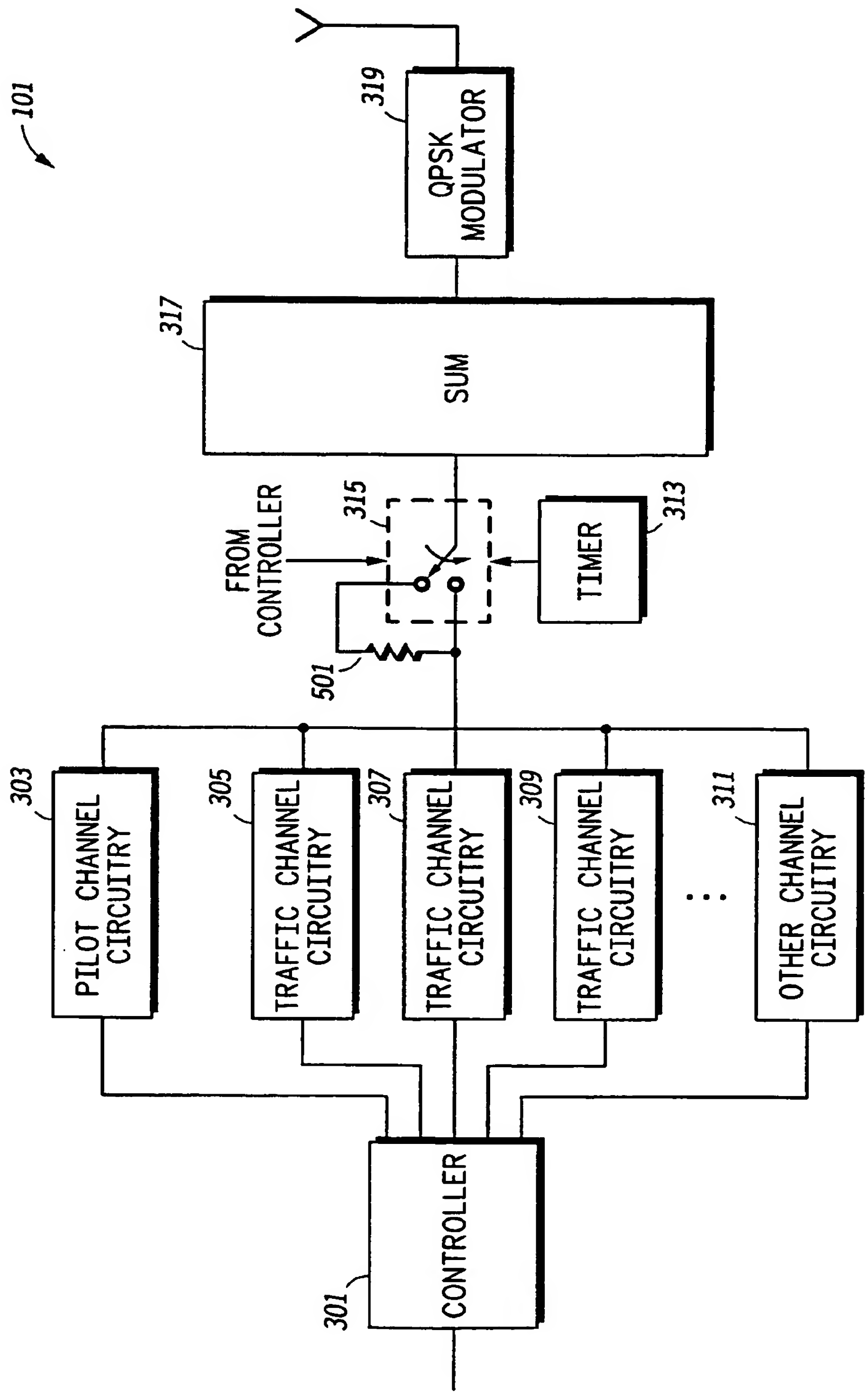
101
QPSK MODULATOR
319
SUM
317
FROM CONTROLLER
315
TIMER
313
501
PILOT CHANNEL CIRCUITRY
303
TRAFFIC CHANNEL CIRCUITRY
305
TRAFFIC CHANNEL CIRCUITRY
307
TRAFFIC CHANNEL CIRCUITRY
309
OTHER CHANNEL CIRCUITRY
311
CONTROLLER
301

FIG. 5

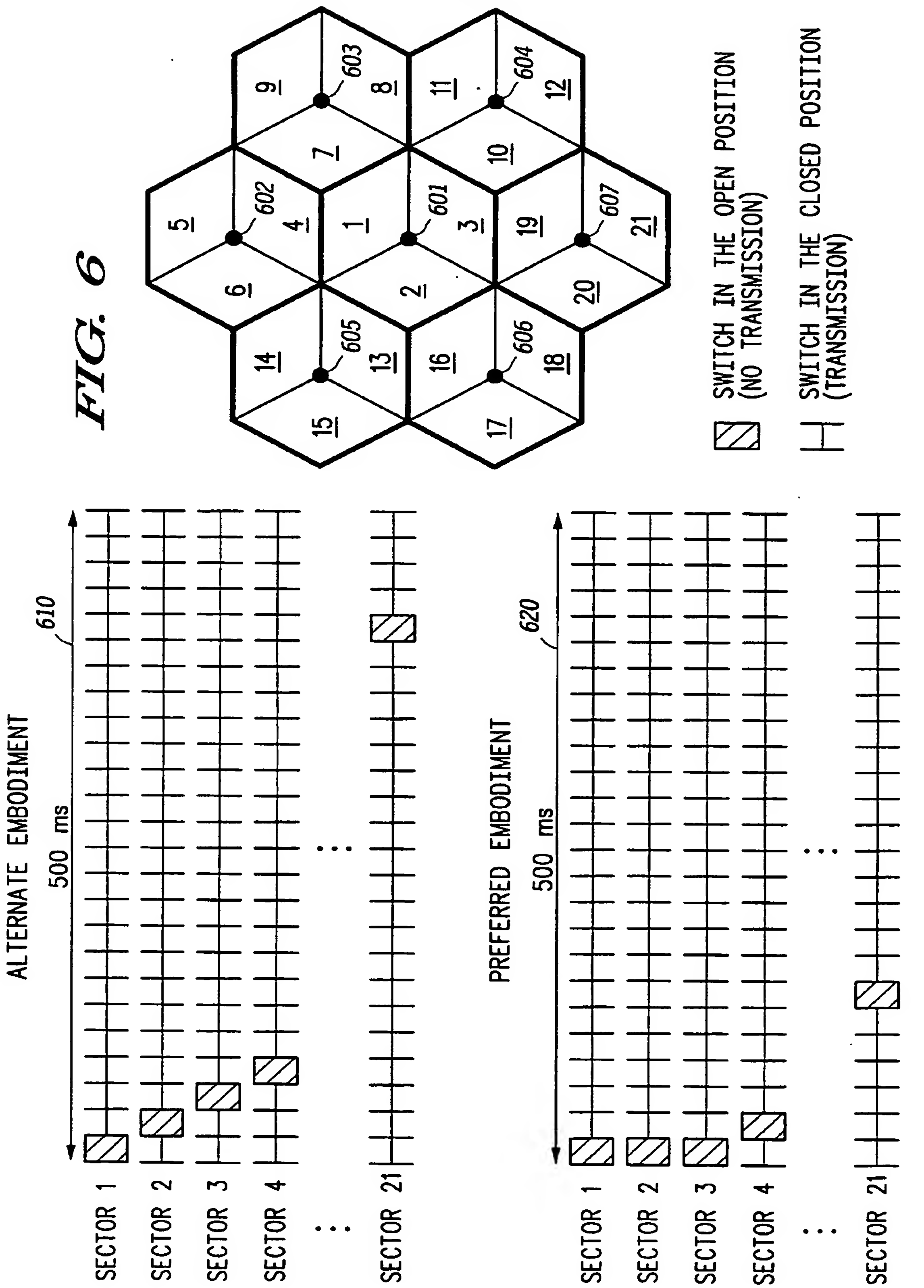
ALTERNATE EMBODIMENT
500 ms
610
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4
SECTOR 21
PREFERRED EMBODIMENT
500 ms
620
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4
SECTOR 21
601
602
603
604
605
606
607
SWITCH IN THE OPEN POSITION (NO TRANSMISSION)
SWITCH IN THE CLOSED POSITION (TRANSMISSION)

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/21963

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :G01S 3/02
US CL :342/357 ; 455/522
According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)
U.S. : 342/457, 387 ; 455/522

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

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NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	US 5,943,014 A (GILHOUSEN) 24 August 1999 (24/08/99) See column 2, lines 48-65, column 15, line 58 to column 16, line 64, and Figures 5-7, 7A, 10A, and 11.	1-18
A	US 5,584,049 A (WEAVER JR. ET AL) 10 December 1996 (10/10/96) See elements 210 and 218.1	1-18

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